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# MYRICA FAYA: POTENTIAL BIOLOGICAL CONTROL AGENTS

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## ABSTRACT

*Myrica faya*, an aggressive alien tree or shrub infesting Hawaiian forests, is native to the Azores, Madeira, and the Canary Islands, island groups in the north Atlantic Ocean. An exploratory trip to these regions was made in search of potential biocontrol agents. This species was found to be generally abundant in these islands, comprising prominent portions of native forests. *Myrica faya* also readily encountered in waste areas and old pastures, hedgerows, and roadsides.

Several diseases and insects were found to attack *M. faya*, some of which were capable of causing severe damage in local areas. However, *M. faya* populations in general did not appear limited by attacks of such agents. Nevertheless, since insect or pathogen behavior may be influenced by new environments as is the host itself, it is recommended that further study be directed at determining the biocontrol potential in Hawaii for certain of the insects and diseases observed in the native habitats of *M. faya*.

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## INTRODUCTION

Myrica faya Ait., commonly known in Hawaii as fire bush or firetree, was introduced into the state during the late 1800s or early 1900s. It may have been introduced as a potential forestry species (Neal, 1965), or as an ornamental by immigrant settlers from its native habitat in the Azores, Madeira, and Canary Islands (Kim, 1969). Whatever the reason for its introduction, M. faya flourished in the environment of Hawaii and rapidly moved into pastures, disturbed forest areas, and wastelands, where it sometimes formed such dense stands that other vegetation was completely shaded out. In some cases it also invaded certain undisturbed forest areas where it was able to compete successfully with the native vegetation.

Myrica faya is considered by several state and federal agencies in Hawaii to be an aggressive noxious weed with no commercial value, and eradication using mechanical, chemical, and biological means has been attempted (Krauss, 1964; Kim, 1969; Walters and Null, 1970; Smathers and Gardner, 1979; Gardner and Kageler, 1982). These eradication efforts have been only partially successful, however, and M. faya is still considered a serious weed pest in the state. Latest estimates show that this species is present on all the Hawaiian Islands except Molokai and currently infests 54,000 acres (Watanabe, 1982), of which 45,000 acres are on the island of Hawaii. Because of high seed productivity and ease of spread by birds and other means, the plant will undoubtedly continue to spread and to reinfest areas from which it was eradicated, unless effective means are found for its control.

A significant part of the area infested by M. faya is closely associated with native vegetation and does not lend itself to control by classical chemical means. A successful technique has recently been developed for killing M. faya and other woody plants with the herbicide Roundup with minimum risk to associated native vegetation[1] (Gardner and Kageler, 1982). The method is labor intensive, however, and probably is not economically feasible for extensive areas.

Myrica faya is only one of several introduced plants that threaten the integrity of Hawaii's native forest ecosystems. Other species, including Passiflora mollissima, Rubus spp., and Clidemia hirta also do not lend themselves to control by chemical means. Biological control (biocontrol) seems to be the only feasible alternative. To

[1]The U. S. Departments of Agriculture and Interior neither recommend the herbicide use reported, nor imply that it has been registered by the appropriate governmental agencies.

address this possibility, a cooperative program was started in 1983 to identify, collect, screen and, release potential biological agents for the control of the major noxious forest weeds in Hawaii. Taking part in this cooperative program are the USDI National Park Service, Hawaii Division of Forestry and Wildlife, USDA Forest Service, Hawaii Department of Agriculture, and the University of Hawaii. As part of this program, we made an exploratory trip to the Azores, Madeira, and Canary Islands, from April 22 to May 25, 1984, to search for potential biocontrol agents on _M. faya_. This report describes the native habitat of _M. faya_ and previous attempts at biocontrol in Hawaii. It reports on potential biological control agents found during the exploratory survey and recommends specific topics for further study.

## NATIVE HABITAT

_Myrica faya_ is a native of the Azores, Madeira, and Canary Islands (Figs. 1 & 2), which, along with the Salvage and Cape Verde Islands, comprise an island group called Macaronesia. The plant has been introduced to Portugal where it has become naturalized, and also was introduced to Florida. Although we also visited Portugal, we did not see _M. faya_ in the field.

### Azores

The Azores Islands are located between approximately 37° to 39° north latitude in the Atlantic Ocean, 1225 km west of Lisbon, Portugal, and 3400 km east of New York (Figs. 1 & 2). They were discovered by the Portuguese about 1427 and first settled about 1439. No people were indigenous to the islands. Currently, the islands are administered as an autonomous region of Portugal. The nine islands form an archipelago about 480 km long. The total land area is 2305 $km^2$, which is less than one-seventh the land area of the Hawaiian Islands (16,633 $km^2$). The largest island in the Azores, Sao Miguel (747 $km^2$) is slightly larger than Molokai, and the smallest, Corvo, is about one-seventh the size of Kahoolawe. Most of the larger islands surpass 1000 m elevation, with Vara Peak on Sao Miguel reaching 1105 m, and Pico Peak on Pico reaching 2351 m.

As with the Hawaiian Islands, the Azores are of volcanic origin, arising from a submarine ridge, and have never been a part of any major land mass. Evidence of volcanic activity can be seen on most of the islands. The most recent volcanic activity occurred on the island of Faial in 1958, when a new volcano was formed about 1 km off the eastern tip of the island, and ash and lava deposits eventually connected it with the main island. Another major eruption occurred approximately 100 years ago when a lava flow of the a'a type about 1.5 km wide reached the sea.

The climate of the Azores is moderated by a branch of the Gulf Stream. Summer temperatures average about 21°C and winter temperatures about 14.5°C. Frost has never been reported along the coast but occasionally may occur above 500 m elevation. Mean annual rainfall at sea level varies from about 700 to 1000 mm. Few weather stations are located at higher elevations but in general rainfall increases 20 percent for every 90-m increase in elevation. Clouds and mists are common at the higher elevations, and the mean relative humidity seldom falls below 88 percent.

The native forests of the Azores were relatively low stature, probably not more than 12-15 m high and consisted primarily of *M. faya*, *Laurus azorica*, *Juniperus brevifolia*, and *Erica azorica*. At the lower elevations, except for areas too rocky or too steep for cultivation, these forests have largely been cleared for agriculture. Much of the area above 600 m elevation is still intact, but trees above this elevation seldom are more than 4-8 m tall. Fairly extensive plantations of *Cryptomeria japonica*, *Eucalyptus globulus*, and *Acacia melanoxylon* have been established on some islands. *A. melanoxylon* has spread widely outside the plantations and is considered a noxious weed in some areas. The introduced species *Pittosporum undulatum* has become naturalized throughout the islands and sometimes forms almost pure, dense stands on disturbed areas.

*Myrica faya* once comprised a significant part of the native forest ecosystem. On two of the islands we visited during the current exploration trip, Sao Miguel and Terceira, few undisturbed areas of native forest remain below 600 m, the highest elevation at which *M. faya* grows in the Azores. It is commonly found, however, along roadsides and hedgerows, in unimproved pastures, and mixed with *P. undulatum*, *L. azorica*, and *E. azorica*, which form dense stands in disturbed areas or on rocky steep slopes of gullies (Fig. 3) and seaside cliffs. In the latter habitat it can be found at sea level (Fig. 4). It is also widely planted for windbreaks and, when properly trimmed, forms an excellent wind barrier (Fig. 5).

Of the four islands of the Azores we visited, *M. faya* is more common on the islands Faial (Fig. 7) and Pico (Fig. 8) than it is on Sao Miguel (Fig. 9) and Terceira (Fig. 10). Faial and Pico are extremely rocky with more recent volcanic activity, and because of this, agricultural development has been somewhat less than on Sao Miguel and Terceira. The eastern end of Faial resembles some of the more recent lava flows on the island of Hawaii. Growth of

M. faya is especially luxuriant on an extensive a'a type lava flow about 100 years old. Here, M. faya is the dominant component of the ecosystem and is mixed with L. azorica, E. azorica, and Picconia azorica. Areas of lava rock still not colonized are covered with the lichen Stereocaulon vesuvianum, which is reminiscent of S. vulcani in Hawaii. On such areas can be found numerous seedlings and young plants of M. faya (Fig. 6). Myrica faya is a primary colonizer of such habitats (Bertelho Goncalves, Azores Forest Service, personal communication).

The small island of Pico is dominated by Pico Peak, at 2351 m the highest mountain in the Azores. The island is extremely rocky and pastures and vineyards predominate. Here M. faya forms extensive, sometimes almost pure stands on old lava flows. Numerous trees of this species also remain on land cleared for pastures. Some of the largest trees we saw in the Azores, up to 15 m tall and 30-40 cm diameter, were in pastures. The species is also commonly planted as windbreaks in the vineyards, and vigorous young seedlings are common in abandoned vineyards.

## Madeira

The Madeira Archipelago is situated in the North Atlantic approximately 850 km southeast of the Azores and approximately the same distance from the European continent. The islands, consisting of the main island of Madeira, the small island of Porto Santo, and three tiny uninhabited islets called the Desertas, lie between 32° and 33° north latitude (Figs. 1 & 2). Total land area for the archipelago is approximately 800 km$^2$, with the island of Madeira comprising 728 km$^2$. The island of Madeira (Fig. 11) is about the same size as Sao Miguel, the largest island of the Azores, and only slightly larger than Molokai. Like the Azores, the Madeira Islands are of volcanic origin and are true oceanic islands. Similarly, no indigenous people lived on the islands at the time of their discovery by the Portuguese in 1420. Currently, Madeira is an autonomous district of Portugal.

The topography of Madeira Island is extremely precipitous. Its sea cliffs are some of the highest in the world, with those at Cape Gerao on the south coast rising almost vertically for 580 m. With the exception of a fairly level high plain on the west end of the island, little level ground can be found. The interior of the island is deeply cut by numerous valleys whose walls sometimes rise almost vertically for 800 m or more. The highest point on the island, Ruivo Peak, is 1861 m above sea level, but several other peaks are more than 1600 m high.

The mean annual temperature at sea level in Madeira is approximately 19$^{\circ}$C, and decreases on a gradient of about 1$^{\circ}$C for each 156 m increase in elevation. Temperatures below zero are rare, even at the highest elevations. Rainfall varies considerably. Along the southern coast, annual rainfall is 500-1000 mm and increases to 1000-1500 mm on the south side between 500 and 1200 m elevation, on the east and west ends, and along the north coast. In the central highlands and extending to lower elevations on the north side of the island, annual rainfall may reach as much as 2500 mm. The central highlands, where most of the existing native forests are found, are covered with clouds and mist about 80 percent of the year (Fig. 12).

At the time of its discovery, Madeira was heavily forested. In fact, the word "madeira" in Portuguese means wood. The original forest type, "laurosilva" or laurel forest, is named after the major components of the ecosystem, four tree species in the Lauraceae family--*Laurus azorica*, *Ocotea foetens*, *Persea indica*, and *Apollonias barbujana*. *Myrica faya* forms an important component of the secondary canopy in these forests along with *Erica arborea*, *Clethra arborea*, *Ilex perado*, *I. canariensis*, and *Juniperus cedrus*.

Fairly extensive areas of relatively undisturbed native forests can be found in the central highlands above 800 m. The lower slopes, however, have been cleared for planting grapes and bananas, the two major crops on Madeira. On steeper slopes can be found plantations of *Eucalyptus globulus*, *Acacia melanoxylon*, *Pseudotsuga menziesii*, and *Pinus* spp.

*Myrica faya* is abundant in both undisturbed and secondary native forests up to about 900 m elevation (Fig. 12). It is also common on lower slopes along roadsides, in hedgerows, and as understory in pine plantations on the northern parts of the island. Except for on the extreme eastern end, however, *M. faya* is not found on the southern part of Madeira. On the steep cliffs on the north side it grows almost to sea level. Unlike in the Azores, *M. faya* is not often used for windbreaks on Madeira. It is, however, much prized for firewood and for making charcoal.

## Canary Islands

The Canary Islands lie in the North Atlantic approximately 90 km west of the African coast between about 27$^{\circ}$ and 29$^{\circ}$ north latitude (Figs. 1 & 2). The seven major islands stretch in an east-west direction for about 645 km. The geological origin of the Canary Islands is uncertain, but it is believed to be volcanic. Unlike the Azores and Madeira, the Canary Islands were inhabited by an indigenous people prior to their colonization by Spain. The indigenous culture was subdued in 1496 and has now been completely assimilated into the current Spanish culture.

The climate of the Canary Islands is essentially Mediterranean, with dry summers and wet winters. The two easternmost islands and southern Gran Canaria are extremely dry, but in general, rainfall increases towards the west. Trade winds strongly affect rainfall patterns, with a zone of precipitation between about 800 and 1500 m on the windward (northeast) side. The lower elevations on the windward side as well as the leeward sides are quite dry. Temperature is extremely variable, both among and within islands. Mean temperature in the winter is about 18°C and in the summer is between 20° and 25°C for the westernmost islands. The difference between the windward and leeward sides of the larger islands is sometimes 10°C. Summer mean temperatures up to 35°C have been recorded for the two easternmost islands while snow is present on the upper slopes of El Tiede (3707 m) on Tenerife for several months in winter.

The native forests of the Canary Islands are of two kinds, laurel and pine. The laurel forests are found on the five westernmost islands, usually confined to the wetter zones on the north sides. These forests have almost been eliminated on Gran Canaria and significantly reduced on Tenerife by the activities of man. Extensive forests still exist, however, on the western islands of Gomera, Hierro, and Palma. These forests are similar to those described for Madeira, and in fact the same four lauraceous species-- *Laurus azorica*, *Persea indica*, *Apollonias barbujana*, and *Ocotea foetens*--dominate the ecosystem. *Myrica faya* also is a common component of these forests, along with *Prunus lusitanica*, *Ilex platyphylla*, and *Salix canariensis*. Forests of endemic *Pinus canariensis* can be found on Palma, Tenerife, Gran Canaria, and Hierro between 1200 and 2000 m elevation. These forests are generally quite open with only a few subcanopy plants.

Because of logistic problems and lack of time we visited only three of the seven Canary Islands: Gran Canaria, Tenerife, and Gomera. On the advice of personnel at the Canary Botanical Garden on Gran Canaria, we did not look for *M. faya* on that island, as--evidently--few plants remain. We did see, however, several large plants of this species in the botanical garden. Therefore, we concentrated on Tenerife and Gomera.

Tenerife (Fig. 14) is the largest of the Canary Islands, roughly triangular, and about 80 km long and 60 km wide at its widest point on the eastern end. It has a land area of 2380 $km^2$, or slightly larger than Maui. A ridge runs almost the length of the island with deep valleys dissecting the sides. The ridge is about 900 m high on the east and increases to about 2000 m on the west where it ends in a vast crater rivaling Haleakala in size. From the floor of the crater at about 2000 m rises the cone-shaped volcanic peak El Tiede (3707 m).

Much of the laurel forest on Tenerife has been destroyed. Three fairly extensive areas of native forest remain, however. One is in the Anaga Mountains, which run from the town of La Laguna to the extreme eastern part of the island. The crests of the main ridge and many of the side ridges contain laurel forests. Myrica faya is common in this area and numerous large trees (>15 m tall and 50 cm diameter) were seen. Another extensive laurel forest occurs between the towns of Erjos and Carrizal Alto on the northwest tip of the island. Much of this area was cut over but has regenerated to a typical laurel forest. There are also fairly large areas of apparently undisturbed forest with M. faya as a significant component. The third extensive area of M. faya is the Orotava Valley above the city of Puerto de la Cruz on the north side of Tenerife. This laurel forest was cleared for cropland and pastures, and perhaps firewood, but large areas have regenerated. Sprouts of M. faya up to 10 m high are common in some areas between 800 and 1200 m elevation. Stumps up to 50 cm diameter with 10 or more sprouts can be seen. These laurel forests change abruptly at about 1200 m into natural and planted stands of Pinus canariensis and plantations of P. radiata and P. pinaster.

Gomera (Fig. 15) is a small, almost circular island approximately 23 km in diameter and with an area of 383 $km^2$. From the central high plateau, of 1450 m elevation, radiate steep-walled valleys that open to the sea. The central highlands contain extensive areas of laurel forests, a major component of which is M. faya (Fig. 13). Much of the area appears to be undisturbed and has National Park status. Myrica faya trees on Gomera were the largest we saw. One tree was estimated to be 75 cm in diameter and more than 20 m tall (Fig. 16). Numerous other trees more than 50 cm in diameter were seen. Small M. faya trees had been planted along several kilometers of the highway through the park. Small scattered trees were also seen along the highway on the north side of the island down to about 200 m elevation.

Fairly large areas of laurel forests that include M. faya occur on the islands of Hierro and Palma (Kenneth Emerson, La Laguna University, personal communication), but we were unable to visit them.

## PREVIOUS ATTEMPTS AT BIOCONTROL

The Azores, Madeira, and Canary Islands have previously been explored by scientists from Hawaii for potential biocontrol agents of M. faya. During March-August, 1955, F. A. Bianchi, a Hawaii Sugar Planters' Association entomologist sponsored by the State Board of Agriculture, visited the three island groups, but observed few insects (unpublished correspondence). Weevils and small caterpillars were sent back to Hawaii but could not be successfully propagated (Krauss, 1964). Bianchi also observed three diseases. Two of them, a shoot blight and a canker, were not further identified. A third, which caused dieback of shoots and branches, was observed commonly in the Azores and Madeira (Bianchi, unpublished correspondence, April 24, 1955). On Bianchi's recommendation, the Hawaii Board of Commissioners of Agriculture and Forestry contracted with Dr. Natalina Azevedo at the Forest Biology Station in Oeiras, Portugal to identify the cause of the dieback and to determine the relative susceptibility of selected forest tree species and plants of economic importance to Hawaii. The causal organism proved to be a species of Dothiorella, which according to the Centraalbureau voor Schimmelcultures in Baarn, Netherlands (Azevedo, 1960) was probably the imperfect state of Botryosphaeria ribis.

The fungus proved to be highly virulent to M. faya in artificial inoculation studies (Azevedo, 1960). However, it was also pathogenic to Casuarina glauca, Schinus molle, Salix babylonica, Persea americana, and Mangifera indica. Because P. americana (avocado) and M. indica (mango) are important economic plants in Hawaii, studies on the fungus as a possible biocontrol agent for M. faya were discontinued.

Noel L. H. Krauss, a Hawaii State Department of Agriculture entomologist, visited the Azores, Madeira, and Canary Islands during 1960 and again in 1962 to search for potential biocontrol agents for M. faya. He also looked for insects on other Myrica species in the southeastern and northeastern United States, Mexico, Costa Rica, and various parts of Africa. A list of the insects and fungi he found was published (Krauss, 1964). Attempts to establish several of the insects from M. faya in Hawaii were not successful. Stocks of a small caterpillar (Carposina ?atlanticella: Carposinidae) infesting green fruits and immature seeds in

Madeira were sent to Hawaii, but all died. Three species of loopers (*Cleora fortunata*, *Cosymbia maderensis*, and *Episauris killiani*) and two of leaf miners (*Gracilaria* sp. and *Lithocolletis* sp.) were also sent to Hawaii, but could not be propagated. A leaf-webbing insect, *Strepsicrates smithiana*, common on *M. cerifera* in the southeastern United States[2], was successfully introduced into Hawaii from that region and established on *M. cerifera*; however, it has not been very effective. A twig blight also occurs on *M. faya* on Madeira and in the Canary Islands (Krauss, 1964). The fungus causing this disease, which also occurred on clusters of green fruits, was identified as *Ramularia destructiva* by the Commonwealth Mycological Institute. No attempt was made to introduce this fungus to Hawaii or to assess its potential as a biocontrol agent. Large blackened galls or knots also occurred on *M. faya* in all three island groups but their etiology was not determined at that time (Krauss, 1964).

Although numerous insects and several fungi have been identified on *M. faya* in its native habitat, to date none have been introduced successfully into Hawaii, so their potential activities and effectiveness in the new environment are not known.

## POTENTIAL BIOCONTROL AGENTS

### Fungi

*Nectria* Canker. Although both Krauss and Bianchi reported the occurrence of cankers, galls, and knots on branches and stems of *M. faya* in the Azores, Madeira, and Canary Islands, neither was able to determine the cause of the problem. We found cankers and galls to be common in all island groups we visited. The symptoms varied considerably, but in general were typical of perennial cankers in the Azores and Canaries, and better described as knots or galls on Madeira. Cankers occurred on small (5 mm or less diameter) and large branches and on trunks of trees of all sizes. On trunks of large trees, cankers were sometimes 30 cm or more long (Fig. 17). Some branches and trunks were completely girdled by the cankers and the parts distal to the cankers died. The canker disease was particularly severe on the island of Pico in the Azores. Some large

[2]After returning to the United States, the senior author observed *Myrica cerifera* at several locations in North and South Carolina. The leaf-webbing insect *Strepsicrates smithiana*, previously introduced into Hawaii by Krauss, was the only insect observed. It was, however, found to be widely distributed and in large numbers. No adverse effect on infested plants was noted. No diseases were seen on *M. cerifera* and most plants were growing vigorously.

trees had numerous cankers and had been killed back to the ground. No cankers were observed on other woody species commonly associated with M. faya, even in areas where cankers on M. faya were common. The disease thus appears to be limited, at least in these islands, to M. faya.

Orange perithecia referable to the fungus genus Nectria were found on some cankers, but not all. However, cultures grown from discolored tissue on the margins of cankers were identical to cultures grown from Nectria fruiting bodies. The cause of the canker disease is therefore likely Nectria sp.

No species of Nectria has previously been reported from M. faya and the species associated with M. faya has not yet been identified. The M. faya fungus belongs to the canker-producing section of the genus Nectria, typified by N. coccinea and N. galigena, according to Dr. Amy Rossman of the National Fungus collections in Beltsville, Maryland, an expert on this genus (personal communication). Work on its species identity is continuing.

Typical cankers like those present on M. faya in the Azores and Canary Islands were not seen on Madeira. Instead, numerous knots, sometimes hundreds, were observed on branches (Fig. 18). These knots were formed by localized hypertrophy of branch tissue as well as increased production of bark. Apparently only a small amount of necrosis was associated with the condition. No fungus was isolated from knot tissue, but fruiting bodies of a Nectria sp. similar to those found on cankers in the Azores and Canaries were found on a few galls.

Several cultures of the Nectria sp. from both cankers and fruiting bodies are stored at the USDA Pathogen Containment Facility, Fort Detrick, Maryland.

Ramularia destructiva. This fungus, previously reported from Madeira and the Canary Islands on M. faya (Krauss, 1964), was found to be widely distributed and locally abundant on all the islands we visited. The most noticeable symptom associated with the fungus was wilting of new shoots. New shoots infected on only one side are often characteristically curved like a shepherd's crook (Fig. 19). Numerous small white sporodochia, the fruiting bodies of the fungus, commonly formed on the infected portions of the shoots even before they died (Fig. 19). Shoots can be killed back for 30 cm or more but more commonly only the terminal 5-15 cm are killed, and heavily infected plants appear to have severe frost damage. Occasionally (on new leaves), the fungus causes circular leaf spots, which are light brown and 5 mm in diameter. The fungus also was seen sporulating on young fruits and staminate flower clusters, where it appeared to be associated with premature drop.

Ramularia destructiva was first described from a specimen of Myrica gale in England (Phillips and Plowright, 1877) and until collected by Krauss in Madeira and the Canary Islands, was known to occur only on the original host. Herbarium records at the Commonwealth Mycological Institute showed that R. destructiva has not been collected on any host species besides M. gale and M. faya, nor was it reported in a list of fungi from the Azores (Dennis et al., 1977). It was reported, however, to occur on M. gale in Alaska, Wisconsin, and New England (U. S. Dep. Agric., 1960). One or more cultures of R. destructiva collected from each island we visited are stored at Fort Detrick, Maryland.

Botryosphaeria dothidea. The disease found by Bianchi and attributed to a species of Dothiorella was thought to be the imperfect state of Botryosphaeria ribis, but the perfect state was never found on M. faya. We especially looked for this disease because of its widespread occurrence and the significant damage to M. faya reported by Bianchi. We were able to find only a few dead branches that could be attributed to infection by this fungus; however, we found in two locations the perfect state of the fungus associated with the Dothiorella state described by Azevedo (1960). The perfect state was determined to be Botryosphaeria dothidea, a cosmopolitan fungus with a wide host range. One of the many synonyms of B. dothidea is B. ribis, thus the tentative name advanced by the Centraalbureau voor Schimmelcultures in 1960 was confirmed. This fungus has been reported from Hawaii on a variety of hosts (Stevens and Shear, 1929; Kliejunas, 1976; Hodges, 1983) and is usually associated with tree stress or wounds. We obtained two new isolates of B. dothidea, which are now stored at Fort Detrick, Maryland.

Cryphonectria sp. On the island of Pico in the Azores, we saw several European chestnut trees (Castanea sativa) with chestnut blight caused by Cryphonectria (Endothia) parasitica. Nearby we found one M. faya tree with a canker on which was fruiting a species of Cryphonectria producing only the conidial state. The same fungus also was found on one tree on Faial. Species of Cryphonectria cannot be readily differentiated on the basis of the conidial state. However, cultures were obtained from both hosts and the M. faya isolate appears to differ from that on chestnut. Attempts to identify the fungus from M. faya are continuing.

Armillaria mellea. This cosmopolitan root rotting fungus was found on a single tree on the island of Pico in the Azores. The typical mycelial fans had almost completely girdled the tree at the base, and the crown showed chlorotic sparse foliage. This fungus is already present in Hawaii.

Miscellaneous. On the islands of Sao Miguel and Pico in the Azores, we observed several areas where M. faya was defoliated. This was especially severe at elevations above 600 m where some twig dieback was also present. At lower elevations defoliation occurred only on the lower branches. We were informed by personnel of the local forest service that M. faya is normally deciduous at higher elevations. We were unable to confirm this, but trees on other islands at the same elevations were not defoliated. On the other hand, we found no evidence of insect damage or pathogenic organisms that might explain the phenomenon.

A blotchy, poorly-defined leaf spot associated with Cercospora sp. was present in many locations. Symptoms were seen on both current and previous years' foliage.

Insects

Carposina sp. Krauss (1964) found the tiny larvae of Carposina ?atlanticella boring into small green fruits of M. faya at Ribeiro Frio, Madeira, during July-September, 1962. He sent infested material to Honolulu, but no insects survived. We observed what is almost certainly the same insect on green fruits on Madeira. Our observations were made at elevations lower than Ribeiro Frio because at the time of our visit, M. faya was flowering only at that location. The tiny brownish-green larvae could be found inside some fruits with no apparent damage or entry point. Other fruits were obviously damaged and frass was evident on the infested fruit clusters (Fig. 20). We estimated that 90 percent or more of the fruits were infested and seeds destroyed at locales where infestation was heavy. No adults or pupae were seen, but larvae were collected and preserved in alcohol for further study.

Green fruits were present at lower elevations in the Azores but no insect damage was observed there or in the Canaries. However, immature fruits in the latter island group were found only in the botanical garden on Gran Canaria. On Tenerife and Gomera most trees were in the early to middle flowering stage. A few trees, however, had fresh mature fruits. Such aberrant fruiting was noted earlier (F. A. Bianchi, unpublished correspondence, May 7, 1955). Insect attack was not evident on these fruits.

Shoot Borer. Small larvae similar to the fruit insect discussed above were found boring into young shoots of M. faya. Infested shoots were hollowed out for 6-15 cm and eventually wilted and died (Fig. 21). General symptoms were similar to those described for Ramularia destructiva but the different causal agents could be discerned easily on close examination. Although the larvae attacking the fruits and shoots were similar to one another in appearance, they were not necessarily always found on the same tree. Some trees had both types of damage, but others had only one or the other.

A few shoot tips showing similar damage were noted on the island of Pico in the Azores, but no larvae were found. The problem was not seen in the Canaries.

We arranged for entomologists on Madeira to collect adults and to investigate the life cycle of the insect(s) attacking the fruits and shoots of M. faya.

Miscellaneous. Other than the insects mentioned above, we saw little damage caused by insects on M. faya. We collected a few weevils, some small beetles, a leaf-binding caterpillar, and a true bug resembling a type of lygus bug; but, with the exception of the leaf binder, none was associated with recognizable damage. Two types of feeding damage on leaves were seen, but the insects responsible were not present. Two scale insects, one identified as the citrus scale (Icerya purchasi) and the other as yet unidentified, were fairly common on M. faya, but also were observed on several associated species.

## SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Myrica faya is generally abundant on all islands we visited, with the exception of Gran Canaria in the Canary Islands. On Madeira and on Gomera and Tenerife in the Canary Islands, extensive areas of relatively undisturbed native forest, of which M. faya is a significant component, are still present. In the Azores, few undisturbed native forests can be found and most of these are at high elevations above the natural distribution of M. faya. However, M. faya commonly grows as a roadside plant, in hedgerows, on steep rocky hillsides and sea cliffs, and is commonly planted for windbreaks. Large relic trees can be found in pastures, especially on the islands of Pico and Faial. On these two islands M. faya was especially common on fairly recent lava flows where it formed almost pure stands and developed luxuriantly. These lava flows were one of the few habitats in which we saw significant quantities of reproduction. Myrica faya is an adaptable plant and grows well in many types of habitat.

Most of the forest stands in which M. faya grows in the Azores, Madeira, and Canary Islands, as well as individual trees and windbreak plantings, are easily accessible by major highways, forest roads, and trails. We thus were able to see an excellent cross-section of M. faya in its major habitats. Also, because of accessibility and ease of travel, we are confident that we saw the most common insects and diseases occurring on M. faya at the time of our survey. None of the insects or diseases we found, however, appeared to limit significantly the growth and development of M. faya in its native habitats, although severe damage was sometimes observed in local areas. We do think, however, that the fruit-feeding caterpillar (Carposina sp.), the unidentified shoot borer, and the fungi Ramularia destructiva and Nectria sp. should be further investigated in a biocontrol program for M. faya. We are aware of situations in other biocontrol programs in which organisms exhibiting a rather benign relationship with the host in the native habitat assume a more virulent nature in the new environment in much the same way as the host itself becomes more aggressive in this situation (Robert Burkhart, Hawaii State Department of Agriculture, personal communication). For this reason an attempt to fully assess the potential effectiveness of an organism on the basis of its observed activity in the original environment alone may not be adequate. Our recommendations to the National Park Service are as follows:

1. Contract with the Madeira Department of Agriculture to collect or rear, or both, adults of the fruit and shoot insects so they can be positively identified; and--if possible--to send suitable material to the quarantine facility at Hawaii Volcanoes National Park for screening.

2. Continue collaborative efforts with experts in the genus Nectria to provide an identification of the species associated with canker disease of M. faya.

3. Apply for an importation permit into Hawaii of cultures of Ramularia destructiva and Nectria sp. for study under laboratory conditions (i.e. to gain necessary basic information on the fungi themselves on optimum temperature for growth, best conditions for sporulation, and best growth medium such that pathogenicity studies can later be initiated).

4. Negotiate with the USDA Plant Pathogen Containment Facility at Fort Detrick, Maryland, for space to screen M. faya and other selected plants for susceptibility to R. destructiva and Nectria sp.

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We are greatly indebted to the Servicos Florestais (Forest Service) in the Azores and Madeira for furnishing transportation and guides. The foresters and botanists who accompanied us were knowledgeable of the local flora and furnished invaluable help in locating M. faya in various habitats. Kenneth Emerson of La Laguna University in the Canary Islands was also helpful in directing us to concentrations of M. faya on the islands of Tenerife and Gomera and in furnishing valuable logistics information. We also thank Brian Sutton of the Commonwealth Mycological Institute for allowing us to use the herbarium and files, Natalina Azevedo of the Portuguese Forest Service for discussing with us her previous work with diseases of M. faya, and William Bruckart and Morris Bonde of the USDA Plant Pathogen Containment Facility at Fort Detrick, Maryland, for their help in securing quarantine permits and maintaining the fungus cultures collected during the survey. We thank Robert Burkhart, Hawaii State Department of Agriculture exploratory entomologist for offering helpful advice, contributing to the success of our trip. The USDI National Park Service Cooperative Park Studies Unit and the Hawaii Division of Forestry and Wildlife financially supported this study.

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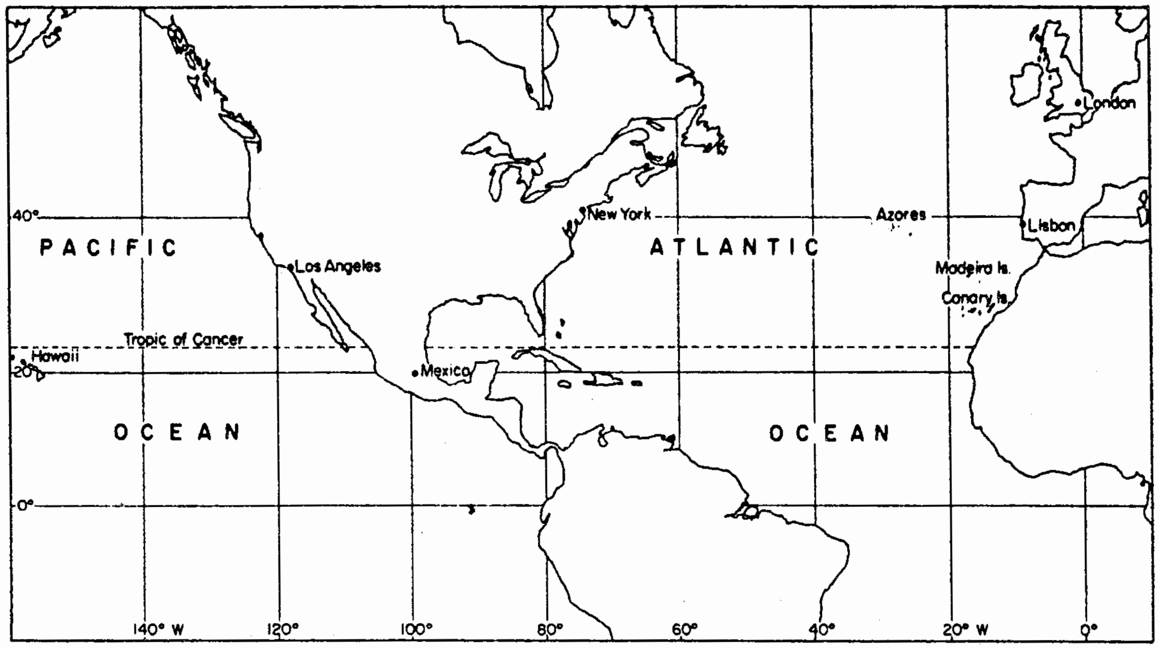



Figure 1. Map showing the position of the Azores, Madeira, and the Canary Islands relative to the Hawaiian Islands.

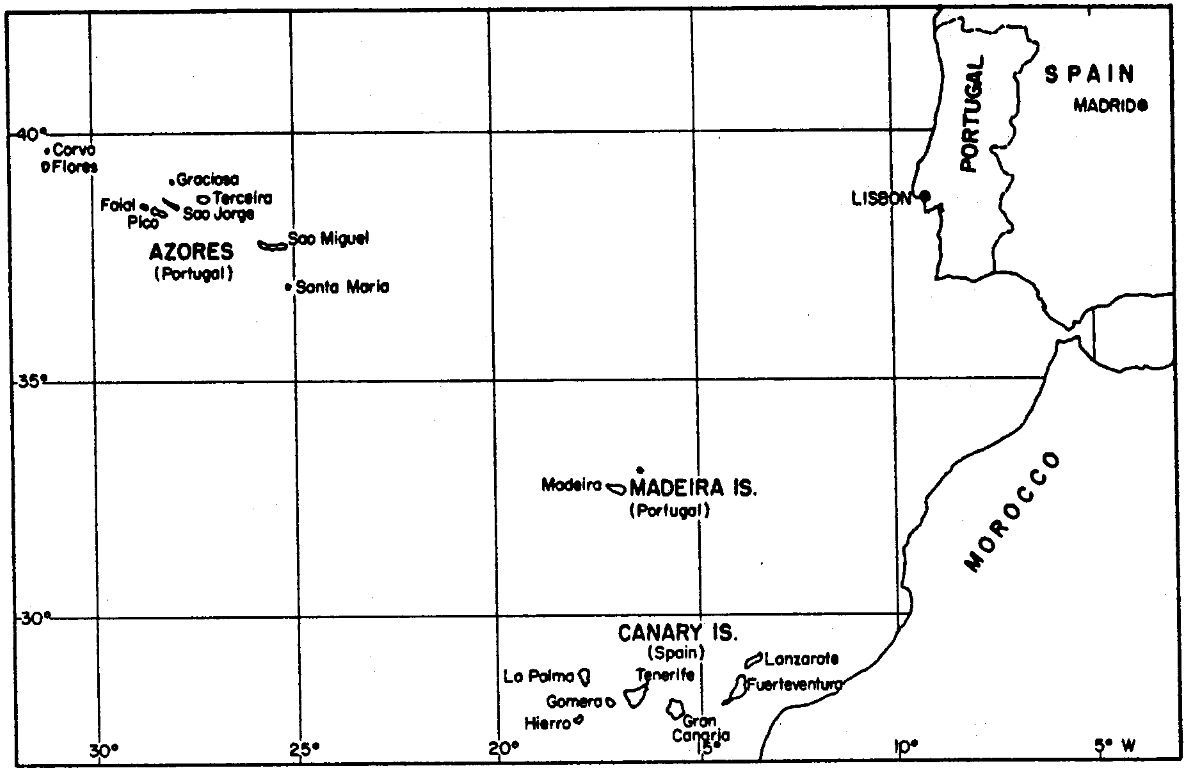
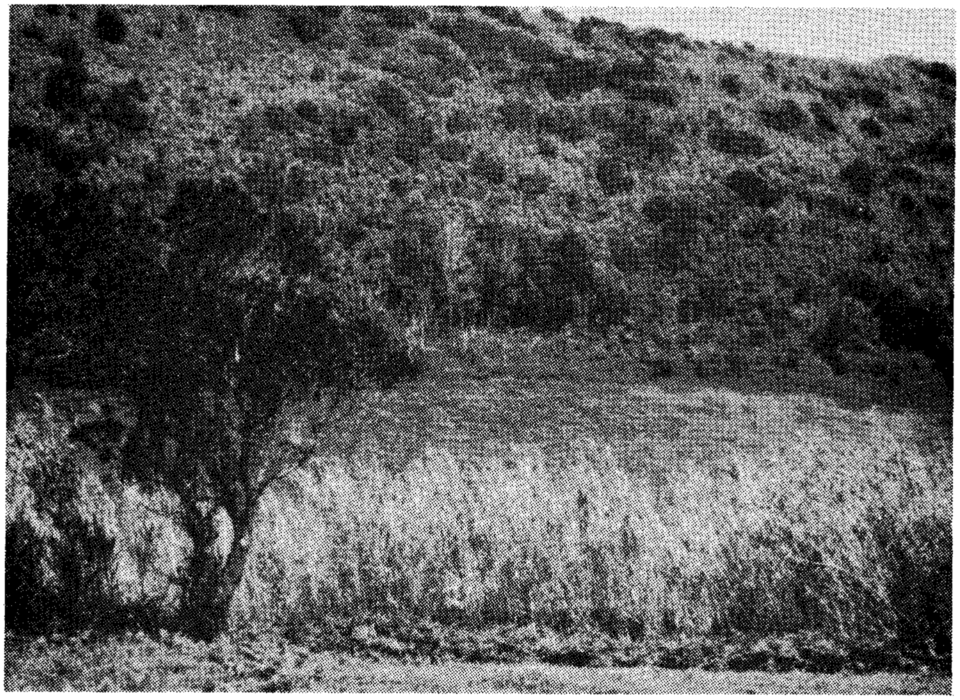



Figure 2. Map showing the positions of the Azores, Madeira, and the Canary Islands relative to one another and to the European and African continents.

Figure 3. *Myrica faya* (darker vegetation) on a hillside mixed with a dense stand of *Pittosporum undulatum*, and in a pasture hedgerow (foreground). Island of Faial, Azores.

Figure 4. *Myrica faya* (darker vegetation) and associated tree and shrub species on a seaside cliff. In such habitats *M. faya* can be found to sea level. Island of Faial, Azores.



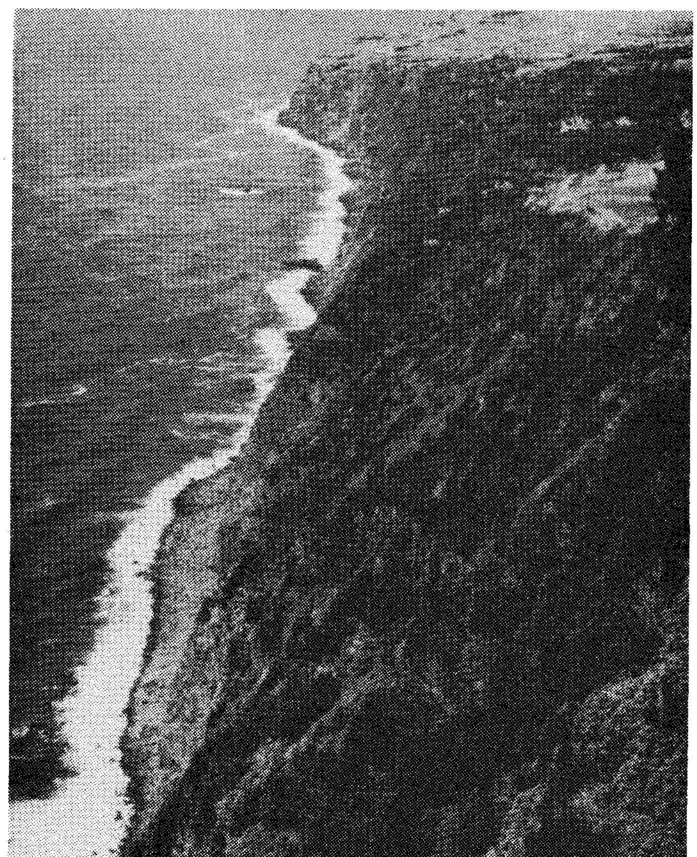
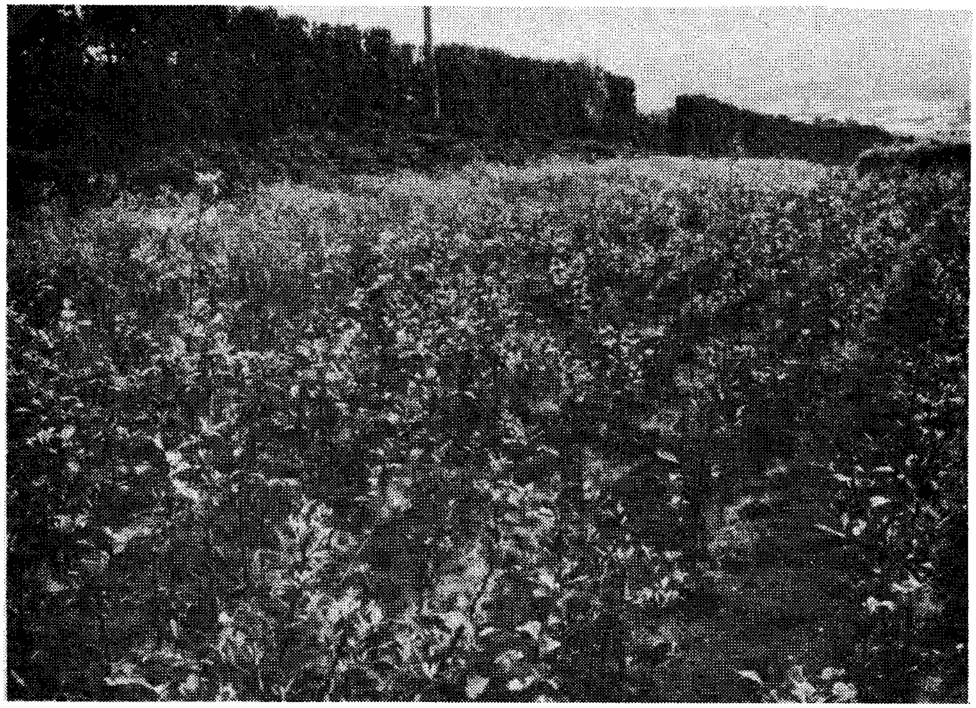


Figure 5. A windbreak of _Myrica faya_ surrounding a small citrus nursery. Island of Terceira, Azores.

Figure 6. A vigorous young _Myrica faya_ plant growing in a'a lava. The lava is covered with the lichen _Stereocaulon vesuvianum_. Island of Faial, Azores.



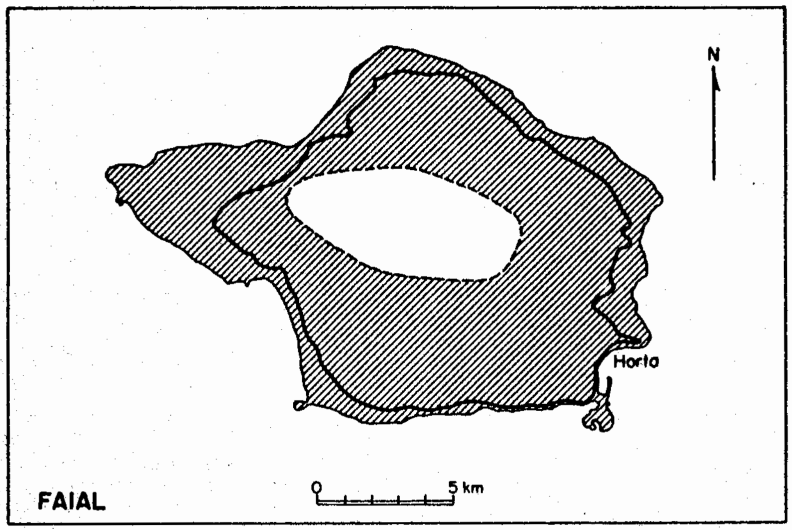



Figure 7. Map of the island of Faial, Azores, showing the areas where <u>Myrica faya</u> was found.

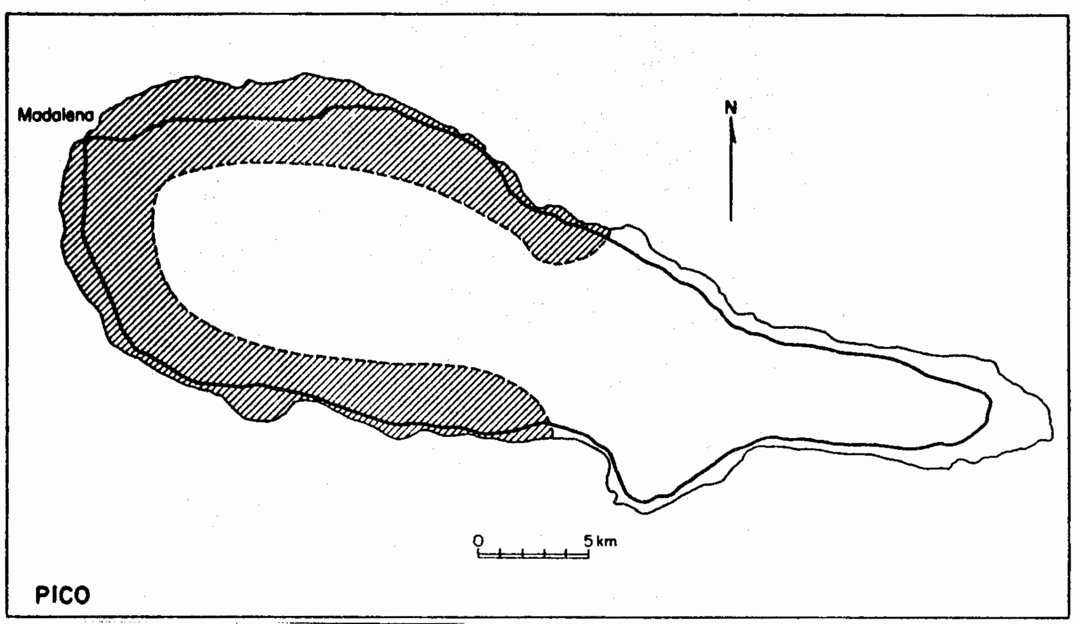



Figure 8. Map of the island of Pico, Azores, showing the areas where <u>Myrica faya</u> was found.

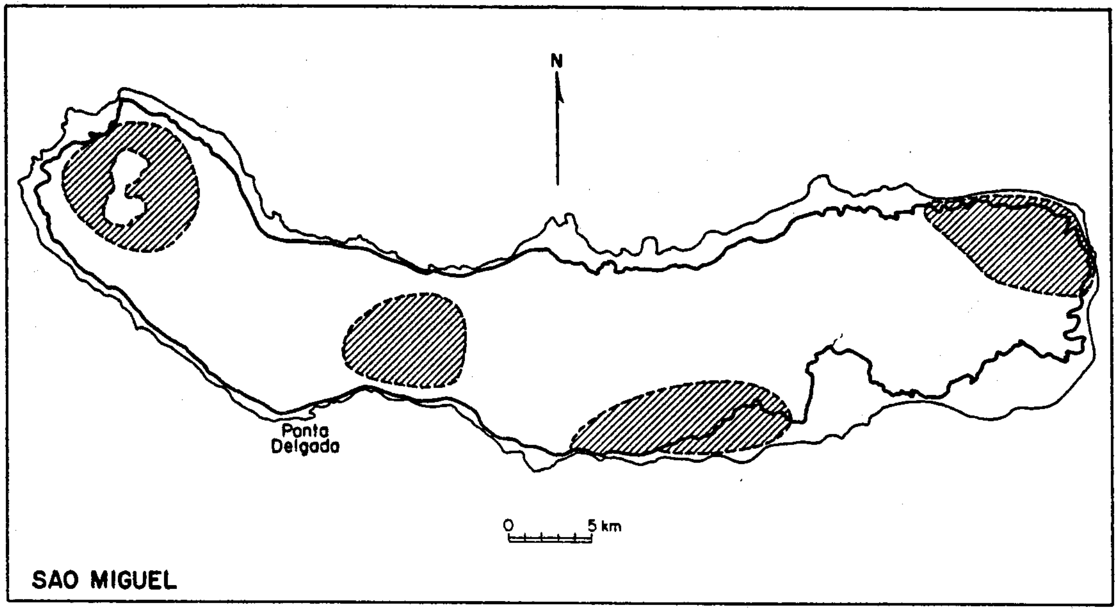



Figure 9. Map of the island of Sao Miguel, Azores, showing the areas where <u>Myrica faya</u> was found.

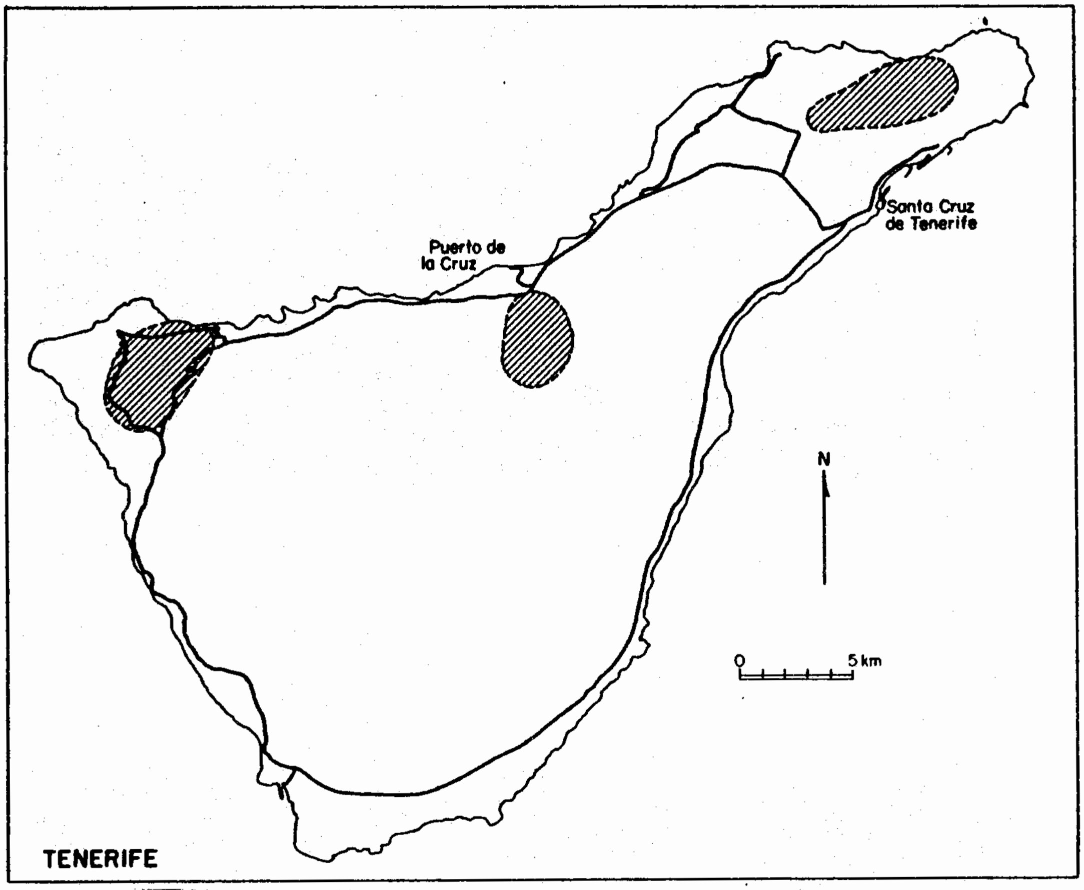



Figure 14. Map of the island of Tenerife, Canary Islands, showing the areas where Myrica faya was found.

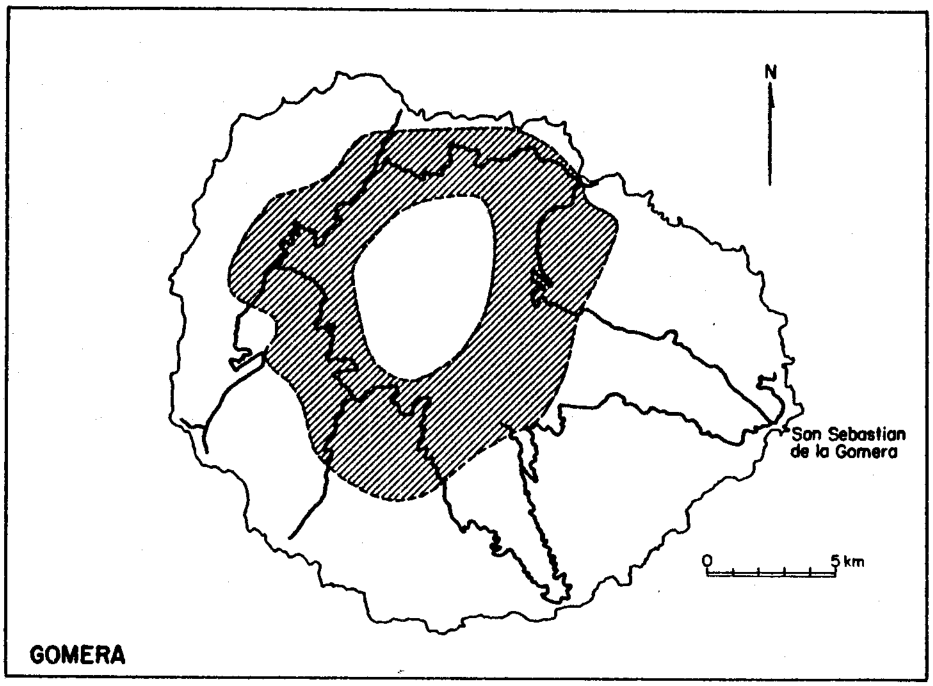



Figure 15. Map of the island of Gomera, Canary Islands, showing the areas where Myrica faya was found.

Figure 16. A large, old *Myrica faya* tree, considered to be the largest tree of the species observed during the exploration trip. Island of Gomera, Canary Islands.

Figure 17. Large trunk cankers caused by *Nectria* sp. on *Myrica faya*. Island of Pico, Azores.

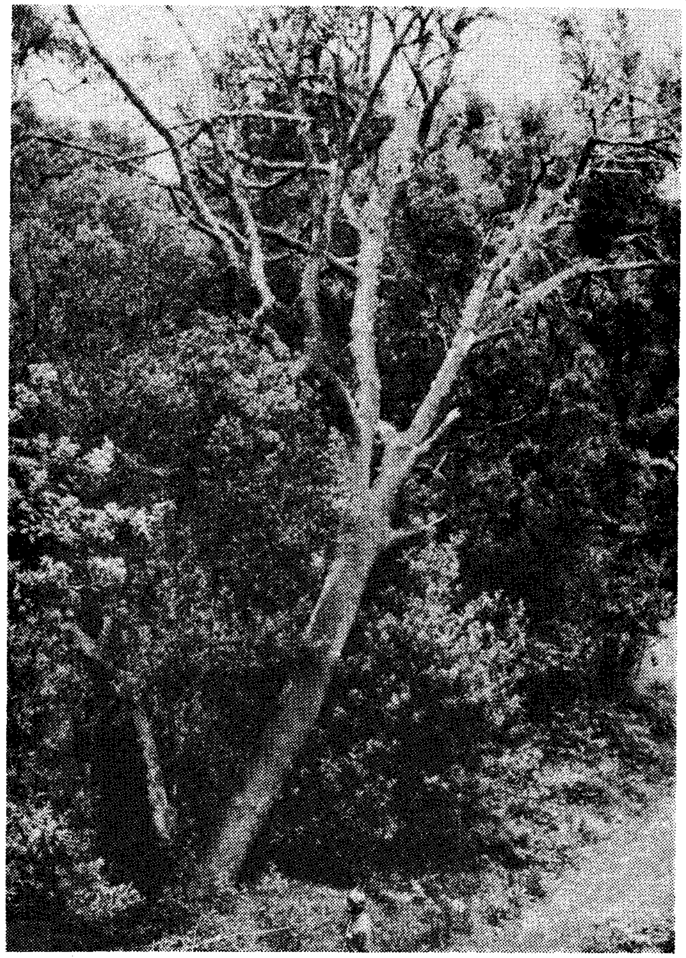


Figure 18. Branch galls or knots associated with <u>Nectria</u> sp. on <u>Myrica faya</u>. Island of Madeira.

Figure 19. A young shoot of <u>Myrica faya</u>, infected with <u>Ramularia destructiva</u>, exhibiting typical shepherd's crook symptoms and white fruiting bodies. Island of Faial, Azores.

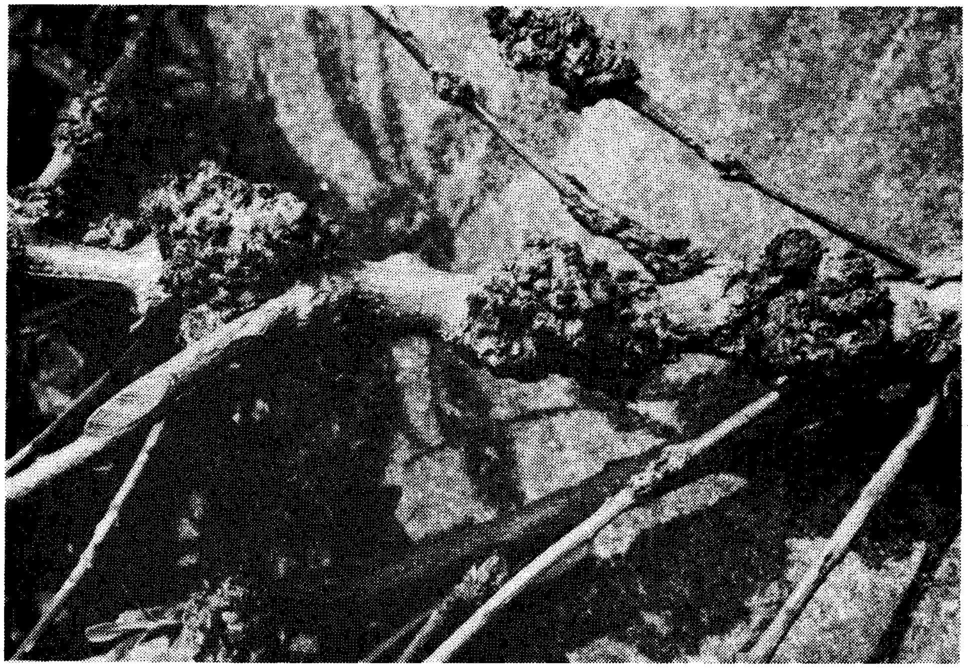


Figure 20. Immature *Myrica faya* fruit heavily attacked by caterpillars of *Carposina* sp. (?*atlanticella*). Note the frass deposits on and around the fruit. Island of Madeira.

Figure 21. A shoot of *Myrica faya* hollowed out by an unidentified tip-boring caterpillar. Island of Madeira.